Utah Department of Transportation
Construction
Manual of Instruction
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CHAPTER 9:
DRAINAGE FEATURES

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901 Pipe, Pipe-Arch; Structural Plate, Pipe and Plate, Pipe-Arch Culvert

A. Study of Plans and Design Review

The life of the roadway depends largely upon proper drainage. It is necessary to examine the drainage facilities to ensure proper sizing and quality of construction. In addition to providing for the passage of existing natural drainage channels through the project, a highway drainage system provides for the collection and disposal to natural drainage channels of all rainfall on the right-of-way and of all ground water flow that may be intercepted during roadway construction. It is attempted during location and planning to provide for the necessary drainage systems. However, particularly with respect to underground water flow, it is impossible to foresee all drainage problems that may result from the construction of the highway.
The Resident Engineer carefully reviews all provisions of the applicable Environmental Document, right-of-way and utility agreements and other commitments, which have a direct bearing on the project. Many of these commitments involve drainage matters. Although ideally all such elements should have been incorporated into the design, in some cases they have been overlooked or require revision. Failure to identify and correct such deficiencies directly affects adjacent property or individuals and is sure to trigger an immediate negative response reflecting on the department's integrity.

Location of Drainage Structure

The alignment and grade of the channel adjacent to the inlet and outlet of the proposed structure is based on the initial project mapping. Any mapping effort can incorporate interpolation errors when generating contours. The magnitudes of these errors are dependent upon the accuracy of the initial survey and data point density in the region of interest. It is common practice for the surveyors to adjust alignment and grade to better match the actual terrain to assure efficient operation of the structure. If the location for any structure as indicated on the plans appears incorrect, or the size improper, or for any reason the structure proposed is not appropriate, contact the Project Design Engineer and take the necessary action to properly correct the situation.

Limiting Heights of Fill

The gage or strength of drainage structures detailed in the plans is that necessary to safely support the weight of the design fill height and legal highway loads on the finished facility. Temporary construction equipment loadings; especially in shallow cover situations, can damage drainage structures. The contractor may need to limit construction loads or place additional temporary fill to prevent damage to culvert structures.
If it is anticipated that the height of fill over a culvert will be materially changed, and the Plans do not provide sufficient data to permit field redesign, contact the hydraulic design section relative to redesign of the structure.

Flow Line Grade

The flow line gradient of a culvert should in general, be the same as that of the channel on each end of the culvert.

Inlets and Outlets

Use extreme care in setting the elevations of inlets and outlets of pipe culverts. Unless the culvert has been specifically over-designed, as with "fish-friendly" culverts, to allow the invert to be buried in the channel, a common mistake is to set them too low with the result that sedimentation soon reduces the effective area of the culvert.

Where a culvert has a straight headwall, or no headwall, the entrance channel should be large enough to permit full utilization of the structure during heavy rains. The channel adjacent to either end of the culvert should be such that there is no abrupt change in the direction of the flow, nor in the flow line grade.

B. Materials

Under normal conditions, the plan lengths of culverts are satisfactory, but field conditions may require a length other than that shown on the plans. The Contractor and his surveyor check the designated plan length in the field, make necessary adjustments in length, and then notify the Resident Engineer in writing of the correct sizes and lengths required for the project at designated locations.

If changes are necessary, at the earliest opportunity, prepare and furnish to the Resident Engineer the modified list of sizes and lengths of culvert pipe so the Contractor may place the order with the supplier at an early date, avoiding a late delivery and delay in the progress of the work. This list is in writing and a duplicate copy retained in the project files. The ordered length of a culvert is in agreement with the length staked in the field and in accordance with the specifications.

If the staking of culverts is not completed prior to the start of construction operations, the furnishing of the pipe lists should be coordinated with the Contractor and their plan of operations. Should the Contractor have the pipe delivered at intervals, it will provide a more favorable opportunity for determining and furnishing the lists of required lengths. However, it is important the list be furnished as soon as is practicable.

Checks are made for positive field identification of each shipment of culvert. Insure that the Manufacturer's Certificate of Compliance report accompanies each shipment. Each shipment is visually inspected for damage and deficiencies in size, shape, length and workmanship before being accepted.
Additional information on sampling and testing pipe culvert is included in the AASHTO Materials Specifications.

C. Excavation

Excavation for drainage structures should accommodate the structure to be installed and should provide sufficient working space and room for forms and bracing if required. Economy will generally dictate that the excavation be the minimum necessary. This is usually desirable for stability. Depending on the depth of the excavation, shoring or sloping of the sides may be required to meet OSHA requirements. Undisturbed natural ground under and at the sides of the structure will ordinarily furnish better support for the structure itself and the embankment to be constructed over it, than will backfill.
Trenches are excavated to a width sufficient to allow for proper joining of the conduit and thorough compaction of the bedding and backfill material under and around the culvert.

Care should be exercised to avoid over excavation. If over excavation should occur the void areas must be filled in layers and compacted to the same density, as the adjacent undisturbed ground so that a uniform support surface is provided for the structure and uneven settlements of the pipe will not occur.

D. Foundation

A uniform, stable, firm foundation of consistent grade under the entire bearing surface of a drainage structure is essential to its long-term stability. The bottom of the excavation should be on solid ground for its full length and width. Culverts, transversely or longitudinally, should not be placed partly on filled ground and partly on undisturbed natural ground because of the probability of unequal settlement, which might distort or break the structure. When such an installation must be made, the embankment should be constructed and thoroughly compacted to a specified height above the elevation of the bottom of the structure. The excavation should then be made in the compacted fill.
When a side hill location is used, the culvert should be benched into the hillside far enough to be entirely on solid ground. If the culvert must be on filled ground, the filled material should be placed in thin layers with proper moisture and thoroughly compacted to provide a foundation nearly comparable to that afforded by the natural ground.
The installation of drainage structures in embankments should be avoided when practicable. This reduces the possibility of installing a foundation subject to settlement, which could cause breakage of the structure or low spots, which will not drain.
Cambering of a culvert grade line should always be considered before installation of the pipe is started. Settlement varies widely depending on the fill height, the depth of foundation soil to a solid stratum, and the compressible character of the foundation soil.
Culverts under high fills may have to be cambered in anticipation of settlement of the underlying grade materials. This is especially true when embankments are placed over saturated fine clay soils.

Camber should not be used as a substitute for foundation stabilization. Poor foundation should be corrected before installing culverts and the amount of camber should be based on the foundation soil profile after stabilization.
Unstable foundation material should be removed and replaced with satisfactory material. If a pipe culvert is to be placed in rock excavation, the rock should be removed as specified, below the bottom of the pipe and a bedding of gravel, sand, or other suitable material should then be placed. When bell and spigot type is used, bedding or foundation should be shaped to conform to the bells so that the pipe will have uniform bearing throughout its length.
After a properly prepared foundation has been achieved a bedding layer appropriate to the type and size of the drainage structure should be placed on the foundation for its full length and width. Note that rigid pipe types require the middle third of the bedding to be loose and not compacted for best performance.

E. Installation

After the foundation and bedding have been completed and alignment and grades have been established for the drainage structures, make sure materials to be used have been tested and no damage has occurred to previously approved items prior to their placement. No installation is ever made on frozen earthwork.
Pipe laying begins at the downstream end of the culvert with the bell or groove ends facing upstream. Care is taken during inspection to see that each section will have full contact with the bedding. When elliptical pipe with circular reinforcement or circular pipe with elliptical reinforcement is used, the pipe is laid in such a position that the manufacturer's marks designating the "top" and "bottom" of the pipe are not more than 5 degrees from a vertical plane through the longitudinal axis of the pipe.
For reinforced concrete pipes 30" in diameter or less, joints are finished on the inside surface before the grout or mortar in the joints has set. For pipes larger than 30" in diameter, the inside joints are not finished until the backfill over the pipe has been completed.
Corrugated metal pipe culverts are laid with the separate sections joined firmly together and with the outside laps of circumferential joints pointing upstream, and with longitudinal laps on the sides.

F. Backfill

The load supporting strength of any pipe is directly affected by the condition of the material around and above the pipe as well as the bedding material. In general, the higher the percentage of compaction of the fill or backfill under the haunches and along the sides of the pipe, the less the pipe will deform under loads. Also, the higher the compaction, the less the material alongside the pipe will consolidate, the consolidation would result in an increased transfer of embankment load onto the pipe. For these reasons, the backfill or embankment material adjacent to the pipe is selected material free from large rocks and lumps, containing sufficient fines so that it will compact to a relatively impervious mass and compacted to a density and width not less than that required by the Specifications or Plans.

Special care is taken to obtain proper compaction under the haunches of the pipe and to place and compact the backfill uniformly on both sides of the culvert. Caution is used to avoid over tamping to the extent that the pipe is lifted out of position.
Many failures of pipe culvert can be avoided by proper backfilling. No pipe can withstand heavy embankment loads unless the backfilling is performed in strict accordance with the Plans and Specifications.
The load that will be imposed on a culvert pipe is affected largely by the manner in which the embankment around and above the culvert is constructed. The maximum height of fill allowable over various sizes and types of pipe and pipe arch culvert is dependent upon backfilling and constructing the embankment over the culvert in strict compliance with
Standard Drawings and the Plans and Specifications.

G. Structural Plate Pipe Culverts, Pipe Arch Culverts

In the construction of multi-plate structures, it is important that the edge of the bottom plates be correctly positioned for alignment and grade before the other plates of the section are bolted so the completed structure will be in proper alignment.
Manufacturers of multi-plate structures supply detailed assembly instructions with their multi-plates, which should be closely followed, as they will prevent creep or spiral. The only way to correct a creep or spiral condition is to remove the plates to the correct alignment and reconstruct the structure.
High strength bolts are used in bolting the plates together. In order for the connections to function as designed, the bolts must be tightened to the specified tension. Impact wrenches are calibrated as specified since over tightening may overstress the bolts and under tightening will not give the connection the required strength. If more than one crew is assembling the structure, the impact wrenches are calibrated to tighten the bolts to the same torque.

905 End Section (For Pipe Culvert and Pipe-Arch Culvert)

See Standard Specification 02614

910 Salvage or Salvage and Relay Pipe

See Standard Specification 02614

911 Relay End Section

See Standard Specification 02614.

915 Downdrain pipe and Pipe-Arch Culvert

See Standard Specification 02614

916 Underdrain

General

Consists of constructing underdrains using the type and size of pipe, or water transporting filters, and granular material or filter fabric, in accordance with the Specifications and in conformity with the lines and grades shown on the plans.
Final design of underdrains at the time of preliminary engineering and preparation of plans is often difficult or impossible due to ground cover, lack of access to the site, and hidden subsurface water or other unknown conditions. Therefore carefully evaluate the conditions on the project as the work progresses, and make or recommend changes in the location or extent of underdrains.
The locations of underdrains are usually determined by soils investigations prior to completion of the plans or during grading operations. Underdrains are placed to lower a high water table, to intercept and dispose of water seeping into the roadway from sources outside of the roadbed, or to intercept and control seepage from the backslope. Edge drains, placed parallel to and near the edge of pavement, are used to intercept seepage through the surface courses. Changes in design locations or the selection of additional locations are documented in writing.
Underdrain pipes are placed with perforations down, except when their only purpose is to transport water. When their purpose is to carry water only, a pipe without perforations is used and it is unnecessary to place the granular material around the pipe. Blind drains are often installed, in which case the water table is lowered by the use of free-draining material.
Rigid inspection is required during construction of all types of underdrain, including blind drains. This assures that any slides from the sides of the trench are removed to ensure the filtering action of the granular backfill and that the holes in the underdrain pipe are not clogged with foreign material that would prevent the underdrain from functioning properly.
If equipment must cross underdrains after installation and prior to paving, the Inspector insists on a rigid covering to protect the pipe from being crushed and the granular material from contamination.
Record the accepted quantities and locations of underdrains and verify that all required tests and certificates of compliance are in the project records.

917 Concrete-Lined Ditch

See Standard Specification 02643

918 Grate and Frame

See Standard Specification 02611

920 Loose Riprap

General

Riprap protects vulnerable soil embankments, dikes and channels from eroding under the effects of flowing water.
A thorough review is made of the plans for locating the riprap noting any field conditions that require adjustments in the preliminary design. The riprap installation should be located in proper respect to high water elevation, direction of flow and angle of side slope, type and security of trees and vegetation, and any springs or drainage water courses that might affect the stability of the design, and blended into already stable areas. In general, riprap should be placed on a granular filter or filter fabric, be angular in nature and should not be placed at steeper than 2 to 1 slopes.
Approve the Contractor's layout before the work begins. Verify not only the Plan location but confirm subgrade and riprap elevations. Care is exercised by the Contractor not to disturb old ground adjacent to the riprap installation.
Check the size of the stone to insure conformity with the Specifications. The individual stones should be placed in contact with each other. All open joints are filled with spalls firmly rammed into place.
Riprap construction is coordinated in order to be accomplished when the embankment or channel subgrade is completed and before erosion is allowed to take place.

Compacted Riprap

See Standard Specification 02373.

Hand-Placed Riprap

See Standard Specification 02373

Keying Riprap

See Standard Specification 02373

Wire-Enclosed Riprap

See Standard Specification 02372